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To:	Shane DeGross, Manager Environmental Remediation, BNSF Railway Company
From:	Helen Dawson, Ph. D, Mike Kavanaugh, Ph. D, P.E., and James Wang, P.E., Geosyntec Consultants, Inc.
Subject:	Comments on the September 2019 Proposed Plan for Quendall Terminals Site, OU1, Renton, Washington

On behalf of BNSF Railway Company (BNSF), Geosyntec Consultants, Inc., (Geosyntec) has reviewed the September 2019 Proposed Plan (PP) for the Quendall Terminals Site, OU1, Renton, Washington. This memorandum presents a summary of Geosyntec's analysis and recommendations to EPA regarding technical concerns with the selected remedy described in the PP for OU1.

The PP indicates EPA's preferred alternative for OU1 includes the application of in situ (in place) self-sustaining smoldering combustion (via the technology marketed as STAR by SAVRON) to treat site contaminants in soil and/or in situ solidification (ISS) to immobilize and contain contaminants in soil. However, the PP provides inaccurate and/or insufficient information to justify the proposed remedy and the approach for implementing it. Key technical concerns Geosyntec has identified with the PP include:

- The PP overstates the effectiveness of the selected remedy (Alternative 7a: STAR+ISS) by asserting that the proposed remedy is expected to achieve groundwater cleanup goals in a reasonable time frame, but provides no technical basis to support that conclusion;
- The PP significantly deviates from the remedial action that was approved by the Remedy Review Board;
- The PP contradicts conclusions in the Feasibility Study (FS) approved by Region 10, specifically the FS conclusion that *none* of the alternatives evaluated in the FS would achieve groundwater restoration goals in a reasonable time frame, without providing the technical basis or other justification for the change in conclusions;

- The PP fails to consider the likelihood that variability in key factors governing the implementability of STAR and/or ISS likely will increase overall remedy implementation costs and duration, and as a result community desired redevelopment of the upland area will be at significant risk of failure.

- The PP's proffered approach for implementing STAR and evaluating its effectiveness at the site is technically inadequate;

- The PP introduces new, undefined mass flux performance criteria for evaluating the ability of proposed remedy to meet site RAOs.

To address the technical concerns identified above, Geosyntec provides the following recommendations:

- The PP should either provide the technical basis for the conclusions in the PP regarding remedy effectiveness and, particularly, for changing the conclusions provided in the FS approved by Region 10 or revise the conclusions. Geosyntec additionally recommends the PP include the FS language recognizing the likely need for a TI waiver for groundwater.

- The PP should provide clarification on the applicability of soil PRGs in STAR-treated areas or consider a variance in those areas. Geosyntec notes that the proposed soil PRGs are set at levels to preclude risk via contact and ingestion and are orders of magnitude lower that levels protective of the soil leaching-to-groundwater pathway. Capping (or similar alternatives that would be expected to be deployed during property redevelopment) will address potential exposures due to contact with surface and near surface soils. The proposed soil PRGs should, therefore, not apply to the deeper saturated zones that will be targeted by STAR combustion.

- The PP should provide a more comprehensive analysis of the cost bounds and potential duration of remedy implementation. The PP should provide the basis for the assumed proportions treated by STAR versus ISS and evaluate the implications of uncertainty in the assumed distribution of DNAPL proportions addressed, the potential need for additional ignition points either laterally or vertically, and the potential need for multiple STAR applications on the cost bounds for Alternative 7a. This analysis should accurately reflect the findings of the STAR pilot study. Geosyntec further recommends that the proposed remedy apply STAR in a single vertical zone and only in highly impacted source areas, and provide flexibility in how, when and where ISS is used.

- The PP should clarify that the conceptual site model and overall soil characterization results will be considered in addition to a TPH criterion, based on the average concentration over a specified volume, to decide whether to treat or not treat a particular location with STAR, and leave to the discretion of the implementing party whether to conduct an additional round of smoldering, contain using ISS, or consider other alternatives based on cost effectiveness and lifecycle impacts.

- Geosyntec recommends that mass flux monitoring be removed as a performance criterion for the remedy. In addition, site specific soil leaching-to-groundwater PRGs should be developed for the site that can provide a basis for determining the extent of applying the mass removal/containment technologies. This provides implementation flexibility and provides a basis for setting decision criteria on when to terminate source removal/containment. Alternatively, if mass flux monitoring continues to be included as a performance evaluation criterion, Geosyntec recommends that EPA provide details about how, where, and when mass flux monitoring will be applied and used. Geosyntec further recommends that EPA clarify the decision process and the criteria that define "success". Additionally, Geosyntec recommends that the flow chart and text of the plan provide flexibility in remedy selection based on cost effectiveness and project lifecycle impacts, including remedy transition criteria that would allow for consideration of natural attenuation as a component of the remedy.

- As noted above the PP should provide flexibility. This can be accomplished with clear remedy/technology decision criteria during implementation of the remedy. In addition, the decision process should also consider the ultimate use of the property and allow adaptive management or flexible strategies with regards to unsaturated soils to meet the public's clearly communicated goal of site redevelopment.

- Regarding both OU1 and OU2, the Remedial Design process will benefit by obtaining additional and current data that will inform design parameters. Incorporating the new data into a more flexible framework and adaptive management process will ensure a more timely cleanup focused on site risk drivers.

In summary, the inclusion of STAR as a component of the proposed remedy, with undefined mass flux performance criteria, adds significantly greater uncertainty to the overall cost and duration of remedy implementation because of the unproven ability of the technology to meet the RAOs, the high degree of uncertainty in characterization of DNAPL distribution and, particularly, the potential need for ISS application after STAR treatment. This added uncertainty likely will lead to significant increases in the cost and duration of the remedy, which likely will preclude the currently proposed and community-desired redevelopment of the upland area.

The bases for our technical concerns and recommendations to address the concerns are described in greater detail below.

1. The PP overstates remedy effectiveness

The PP overstates the effectiveness of the selected remedy (Alternative 7a: STAR+ISS) by asserting that the proposed remedy is expected to achieve groundwater cleanup goals in a reasonable time frame and for the same cost as Alternative (7: ISS only), but provides no technical basis to support the conclusion that inclusion of STAR favorably impacts the overall remedy effectiveness, cost or duration. To our knowledge, no additional groundwater modeling has been conducted to support this conclusion.

The PP further states that "*smoldering combustion is expected to permanently destroy the significant sources of DNAPL contamination in the upland areas"* based on the results of a field pilot study conducted at the site. Geosyntec understands that STAR has the capability to significantly reduce total petroleum hydrocarbons (TPH) under the right conditions, but only in areas where TPH levels are above 3000 ppm and are present in sufficient and contiguous volume to maintain combustion. However, the STAR pilot study conducted at the site was able to achieve sustained combustion in only one of two test areas. Sustained combustion and TPH reduction of 73% to 99% were achieved in one area; combustion was limited and TPH reductions were considerably lower in the other area. Test results in both areas showed many COCs remained above the soil PRGs listed in PP Table 6-1 even in the area of "successful STAR" implementation. For example, naphthalene remained above its soil PRG of 3.8 mg/kg by factors ranging up to 25 times higher than the PRG in 10 out of 12 of the "successfully-treated" post treatment soil samples. Additionally, the STAR pilot study report noted that heterogeneous contaminant distribution and, especially, the presence of contamination in discrete layers will likely require additional ignition points and increase the cost of STAR implementation in those areas. It should be noted that the Remedial Investigation (RI) (Section 4.4) indicates that, in general, DNAPL is found within several discrete soil layers or thin lenses rather than in one continuous pool. These site-specific data do not support EPA's conclusion that STAR is expected to destroy the significant sources of DNAPL contamination. Rather, the STAR pilot test results indicate that, while STAR may remove some DNAPL mass in some areas, substantial fractions may remain.

Geosyntec recommends that EPA either provide the technical basis for the conclusions regarding remedy effectiveness or that it revises the conclusions accordingly. Geosyntec also recommends the PP accurately reflect the findings of the STAR pilot study and explicitly consider the potential need for more STAR ignition points in areas of heterogeneous DNAPL distribution in the calculation of overall costs.

Geosyntec further recommends that EPA provide clarification on the applicability of soil PRGs in STAR-treated areas or consider a variance in those areas. Geosyntec notes that the proposed soil PRGs are set at levels to preclude risk via contact and ingestion and are orders of magnitude lower that levels protective of the soil leaching-to-groundwater pathway. Capping and redevelopment will address potential exposures due to contact with surface and near surface soils. The proposed soil PRGs should, therefore, not apply to the deeper saturated zones that will be targeted by STAR combustion. In addition, remedy flexibility and a technically defensible set of decision criteria for remedy implementation is required due the limitations of STAR as noted above.

2. The PP contradicts conclusion in the approved FS.

The PP includes statements that contradict conclusions in the approved FS, without providing the technical basis or other justification for the change in conclusions. For example, Page 11 states, regarding Alternative 7 (ISS), that "*no active treatment is included in Alternative 7 because, by stabilizing DNAPL in soil, contaminant concentrations will be immobilized, resulting in significant reductions to groundwater contaminants and achievement of PRGs in groundwater in a reasonable timeframe (25 to 30 years).*" No basis is provided in the PP for the conclusion that Alternative 7 will achieve groundwater PRGs in 25-30 years. Nor is any basis provided for the conclusion that Alternative 7a will achieve groundwater PRGs in a reasonable time frame. In fact, the FS concluded that for *"Alternatives 1 through 10 [i.e., all Alternatives], one or more of the MCLs for benzene, benzo(a)pyrene, and arsenic would not be met throughout the plume in a reasonable restoration time frame. Therefore, to satisfy this criterion, a TI waiver would likely be required for all alternatives."* We agree with this assessment provided in the FS.

Geosyntec recommends the PP include the FS language recognizing the likely need for a TI waiver.

3. The PP fails to consider the likelihood that variability in key factors governing the implementability of STAR and/or ISS will increase overall remedy implementation costs and duration.

The PP makes several unsubstantiated assumptions about the implementation of STAR at the site and does not consider the impact of divergence from those assumptions in estimating the overall cost and duration of the remedy. The key assumptions in the PP are that STAR will successfully address 60% of the significant DNAPL sources at the site, that only one ignition point per location will be needed in areas where STAR will be applied, and that the radius of influence will be 7 feet where STAR is applied. These assumptions are largely dependent not only on the concentration, but also on the lateral and vertical distribution of DNAPL masses at the site, which SAVRON identified as key factors governing the implementability of STAR at the site. The uncertainty in

these technical factors likely will lead to significant increases in the cost and duration of the remedy, which will slow or preclude the community-desired redevelopment of the upland area.

The PP does not consider the cost implications of different assumed proportions of DNAPL distribution addressed by STAR versus ISS. The PP (Page 13) states that "*for the purposes of developing a cost estimate, it is assumed that smoldering combustion will destroy approximately 60 percent of the significant DNAPL sources and solidification will be used to treat the remainder*." EPA appears to assume STAR will be successful even in areas that were found to pose problems for sustained combustion during the field pilot study. Data from the RI suggest that DNAPL distribution at most of the site is more consistent with the unsuccessful pilot location and, therefore, extrapolation of the results from the successful pilot location to the entire Site is speculative. No basis is provided for the assumed percent of DNAPL that is anticipated to be destroyed by combustion or contained by ISS and no analysis of the cost implications is included. These analyses are needed to evaluate remedial options, inform the redevelopment plans for the site, and determine what benefits, if any, are obtained by using STAR.

Similarly, the cost implications of potential changes in the volume and areas targeted by STAR versus ISS are not discussed in the PP. Table B-2 in Appendix B shows the assumed volumes to be treated by STAR or contained by ISS, but volumes do not appear to overlap; i.e., the PP does not consider cost increases due to any required application of ISS in areas already treated by STAR, which the PP states may be needed. Additionally, no technical justification is given for assuming that ISS will be used in areas with DNAPL thickness less than 4 feet, while—presumably—STAR will not be applied in those areas, yet the areas included in the STAR sectors encompass areas with DNAPL thickness less than 4 feet.

Additionally, the PP does not discuss the cost implications of SAVRON's strategy for addressing uncertainty regarding the total number of ignition points required for treatment at the site or for the potential need for multiple rounds of treatment. The STAR pilot study report noted that "*there are two key uncertainties that will affect the total number of ignition points required for treatment at the Site: variability in the distribution of contaminant concentrations sufficient for self-sustaining smoldering (i.e., greater than 3,000 to 5,000 mg/kg for IP installation)* [which also influences the radius of influence of individual ignition points], *and presence of multiple layers of contamination requiring more than one ignition point (IP) installation depth at a given location.*" The total costs for STAR treatment may increase or decrease from the base case, depending on the balance of these two uncertainties across the Site. The PP does not provide an analysis of the cost implications of these uncertainties, whether higher or lower. These analyses are needed to evaluate remedial options, inform the redevelopment plans for the site, and determine what benefits, if any, are obtained by using STAR.

Geosyntec recommends that EPA provide the basis for the assumed proportions treated by STAR versus ISS and evaluate the implications of uncertainty in the assumed proportions of DNAPL soil volumes addressed, the potential need for additional ignition points either laterally due either to smaller radii of influence or vertically due to layered contamination, and the potential need for multiple STAR applications on the cos bounds for Alternative 7a. Geosyntec further recommends that the proposed remedy apply STAR only in highly impacted source areas and provide flexibility in how, when and where STAR or ISS is used based on development plans/commitments (i.e. saturated zone was treated with STAR or ISS and planned development includes capping of the overlying soils). We see no justification for using ISS in areas where STAR is applied.

4. The PP's proffered approach for implementing STAR and evaluating its effectiveness at the site is technically inadequate.

The PP uses 3,000 ppm soil TPH as both a decision criterion for implementing the smoldering combustion remedy (Phase 1) and as a performance criterion for assessing the success of STAR treatment but does not provide details on the volume of soil to which that criterion is applied, either during pre-treatment characterization or post-treatment verification. Geosyntec notes that 3,000 ppm is not a clean-up level. Smoldering combustion (STAR) generally requires an initial soil TPH greater than 3,000 ppm to support sustained combustion. The smoldering reaction can 'jump' or maintain combustion over small areas with lower concentrations; however, the reaction may not be sustained through sufficiently large areas with less than 3,000 ppm. Page 13 of the PP states that *"… if soil intervals are found that still exceed 3,000 ppm after the first round of combustion treatment (e.g., in highly heterogeneous areas), an additional ignition point may be installed to re-treat at that location."* However, while an area may contain small, discrete (laterally and/or vertically) intervals with greater than 3,000 ppm TPH after one round of STAR treatment, they may occur in non-continuous areas that may not provide sufficient mass to support sustained combustion in another STAR treatment.

Geosyntec recommends the that the selected remedy provide for consideration of the conceptual site model and overall soil characterization results, in addition to a TPH criterion, and that the TPH criterion be based on the average concentration over a specified volume, to decide whether to treat or not treat a particular location with STAR, and leave to the discretion of the implementing party whether to conduct an additional round of smoldering, contain using ISS, or consider other alternatives based on cost effectiveness and lifecycle impacts.

5. The PP introduces new, undefined performance criteria—mass flux monitoring—for evaluating the ability of proposed remedy to meet site RAOs,

The PP proposes a "mass flux" evaluation as the basis for determining whether additional treatment with STAR or ISS is needed but offers no details on where or how mass flux is to be calculated or what constitutes "acceptable" mass flux and over what timeframe. Additionally, the text of the PP and the various management decision flow charts provide contradictory information. In the text, groundwater mass flux is discussed as a criterion for determining the need for ISS, but in the flow chart the ISS remedy appears to be automatically required, with flux measurements shown only as data supporting the remedy design. In effect, mass flux serves as an added RAO that is not consistent with ARARs, is subject to significant uncertainty, and may pose a major roadblock to redevelopment.

The Step-by-Step process shown on Page 13 of the PP (Page 13) indicates *"passive flux monitoring results"* will be used as the basis for determining whether additional treatment with STAR or ISS will be needed to meet RAOs. The PP further states that *"after it is determined that all combustion treatment is completed, … a relative comparison of post-treatment of groundwater flux data with the baseline groundwater flux data will be used to determine if Phase 2 in situ solidification is needed for additional source treatment." "The need for additional source treatment following combustion [also] will be determined based on…. soil core characterization data."* However, the PP offers no details on how or where or when either baseline flux or post-treatment flux will be monitored, what target mass flux criteria will be used to determine whether Phase 2 (ISS) is required and how it will be monitored or calculated. It also is not clear where and over what time frame the target mass flux criteria will need to be achieved in order to stop active remediation. Finally, it is not clear how soil characterization data will be considered. No additional rationale is provided to justify why this metric is incorporated into decision making for implementation of the remedy. We find the mass flux concept particularly concerning as disagreements over this issue could add to significant project delays.

Geosyntec recommends that mass flux monitoring be removed as a performance criterion for the remedy and that, instead, soil leaching-to-groundwater PRGs be developed for the site. Alternatively, if mass flux monitoring continues to be considered for performance evaluation, Geosyntec recommends that EPA provide details about how, where, and when mass flux monitoring will be applied and used. Specifically, Geosyntec recommends including a range of mass flux levels above which ISS is needed and below which natural attenuation would address the remaining contamination within a reasonable time frame. Geosyntec further recommends that EPA clarify the decision process and the criteria that define "success", specifically the metrics for determining when treatment of a sector is considered complete and successful and include an exit strategy. Geosyntec recommends that ISS be implemented only in areas not treated by STAR and

only if the mass flux criterion is not met in those areas. Additionally, Geosyntec recommends that the flow chart and text of the plan provide flexibility in remedy selection based on cost effectiveness and project lifecycle impacts, including defining explicit decision criteria that would allow for consideration of natural attenuation as a component of the remedy.